REMARKS/ARGUMENTS

The rejection to the claims is based essentially on a difference in the understanding of certain terminology used in the claims. Although applicants do not accept the Examiner's position and provide some additional evidence as discussed briefly hereinbelow, to avoid the issue, applicants have incorporated into the claims, a definition of the terms which is consistent with their intended meaning as explained in the last AMENDMENT, and is also described in detail in the specification on pages 21 and 22. With respect to the definition now being used, applicants note especially the discussion on page 21 in the last paragraph; and also the methods for confirming the constant drying rate period and the falling drying rate period discussed in the third paragraph on page 22 (that is by measuring the surface temperature). The method in the last paragraph on page 22 which involves directly measuring the water content, is also noted.

In view of the clear definition of the terms described in the specification and their incorporation into the claim, it is submitted that the issues raised by the Examiner are avoided.

As evidence that these definitions are consistent with the understanding in this art, there is annexed hereto some pages from a textbook entitled "MODERN COATING AND DRYING TECHNOLOGY" which support applicant's position and to which the Examiner's attention is directed. In particular, at page 275, the last section refers to a "constant rate." This section includes a definition of the "constant drying rate phase" as the period in which the rate of evaporation remains constant. There is an explanation provided including an explanation that the heat input is available to evaporate the solvent and therefore an increase in heat input increases the drying rate and *vice versa*. As is further explained in the last several lines on page 275, the "temperature equilibrates at a level that balances the rate of heating with the rate of evaporative cooling." The falling rate is described in the section beginning near the end of page 276 and includes a typical drying curve on page 277 showing the constant rate and the falling rate (note that the curve is read from right to left with respect to a decrease in moisture content).

Referring to the AMENDMENT filed October 27, 2005, the art-related rejections are based on the Examiner's interpretation of the meaning of the claims which applicant believes is not correct. However, with the introduction of the definitions from

the specification, applicants' arguments, as previously presented, are supported by the terms as defined in the claims (as well as the specification). In view thereof, it is requested that the earlier arguments be re-considered and that a favorable action on the merits be issued.

In view of the above, it is submitted that the present invention is not shown or suggested by the cited art. Withdrawal of the rejections and allowance of the application are respectfully requested.

Respectfully submitted,

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Enclosure: Pages from "MODERN COATING AND DRYING TECHNOLOGY"

MODERN COATING AND DRYING TECHNOLOGY

EDWARD COHEN

WILEY-VCH

CHP1734)UX 31TR.
(JP2001-373510, 2001-164421)

MODERN COATING AND DRYING TECHNOLOGY

EDITORS
EDWARD COHEN EDGAR GUTOFF
[illegible]

[illegible]

[illegible] attention to the precision application technology needed to produce high performance coatings. It also discusses limitations in the speed or thickness of the coating, causes of various defects that occur, handling of the web or support, drying of the coated web, and ways in which the surface chemistry of both the coating fluid and the coating support affect the process.

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commonly used, but a chart can be constructed for any gas–vapor system.

7.3 Drying Regimes

One approach to analyzing the drying process is to recognize that it is actually composed of at least four distinct and easily identifiable processing regions: predryer, constant rate, falling rate, and equilibration. Coating behavior differs in these regions so we will consider them separately in the following sections. Although most of the drying occurs in the constant and falling rate zones, the behavior in the other regions can also be important.

We can examine the nature of these regions by following the temperature behavior of the coating as it leaves the applicator and is carried through the dryer and wound up. Figure 7.2 identifies the characteristics of a typical plot of the drying regimes. In this figure, the bulk average film temperature of the coating is plotted versus the dryer length. Because we know the coating speed, this plot can also be shown as residence time versus temperatures.

The coating used in this example represents a gelatin type that is coated above the gelation point. After the coating is applied, it cools in the transition region, then enters the dryer to be dried in a series of drying zones. The constant temperatures indicate the constant rate zone. The coating then enters the falling rate zone, as indicated by the temperature, which continues to rise until all the solvent is removed, and then passes into the equilibration zone. The conceptual clarity of this process provides another example of the benefit of using the heat transfer analogy.

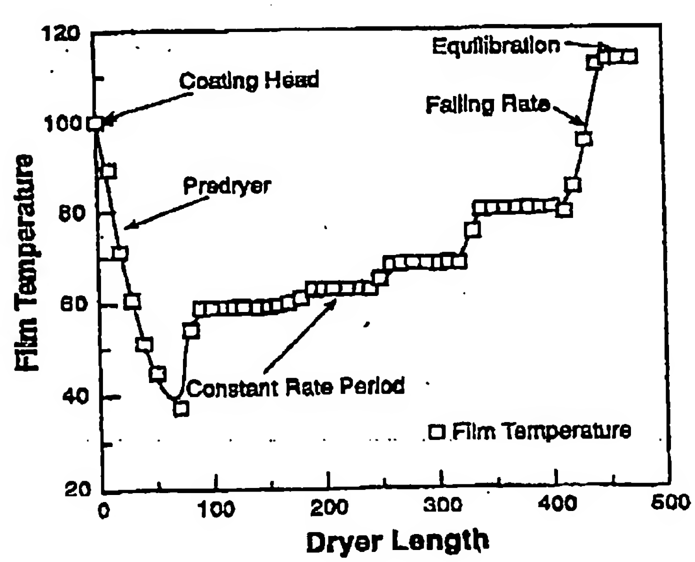


Figure 7.2
Drying regimes.

The length of the falling rate compared to the constant rate period depends on the nature of the coating, that is, the binder, solvent, concentration diffusion characteristics, and nature of the dryer. For a water solvent, the coating film temperature would approximate the wet bulb temperature in a constant rate period for a single-sided dryer and it would be significantly higher in the falling rate period.

7.3.1 Predryer

In most applications coating solutions are applied and then the web moves into the dryer. With low volatility solvents, such as water, and in low temperature environments, little drying occurs in the coating region. However, with volatile solvents drying can take place on the applicator, such as on the slide of a coating bar, or in the curtain. In some processes, such as spin coating, drying and coating occur simultaneously.

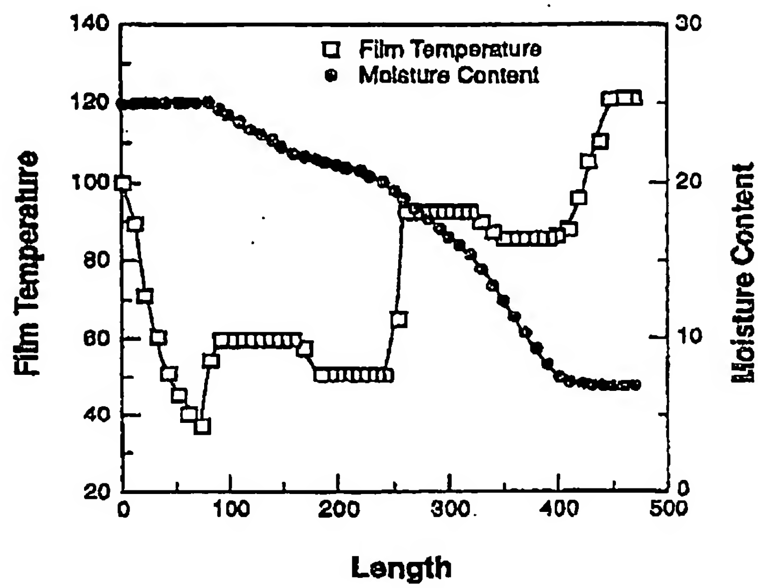
The space between the coater and the dryer is often overlooked as part of the process. Yet this can be a key area, particularly when defects are being created in the coating. Depending on air conditions and solvent volatility, some drying can occur here. Ambient, poorly controlled air can introduce variability, and if the air is not as clean as the drying air, contaminants that create nonuniformities can be introduced into the coating in this transition region. This can also be the area in which the levelling process starts.

7.3.2 Constant Rate

The proper definition of the constant drying rate phase is exactly what the term says; a period in which the rate of evaporation remains constant. Here the rate of drying is limited by external mass transfer resistance, but the rate of drying can vary with distance (if the dry bulb and wet bulb temperatures differ in different zones) and with time (as the web temperature is approaching its equilibrium value, the web should be stated to be in a transitional phase with external mass transfer limitation). In this region, all of the heat input is available to evaporate the solvent, which can move freely to the surface boundary layer where it can be carried away. Increasing the heat input increases the drying rate and reducing it lowers the rate.

Although the division between constant rate and falling rate periods is conceptually attractive, such a distinction oversimplifies reality. Consider the drying process illustrated in Figures 7.3 and 7.4. The coating enters the dryer with a high solvent concentration and at a low temperature, after the initial chilling. At the entrance temperature, the vapor pressure of solvent over the coating and the rate of evaporation are low. Meanwhile, because the entry temperature is low, the rate of heating is high, so the web temperature increases. As the coating heats, the vapor pressure, drying rate, and rate of evaporative cooling all rise. The temperature equilibrates at a level that balances the rate of heating with the rate of evaporative cooling. If the drying rate re-

Figure 7.3
Nondiffusion limited drying curve.



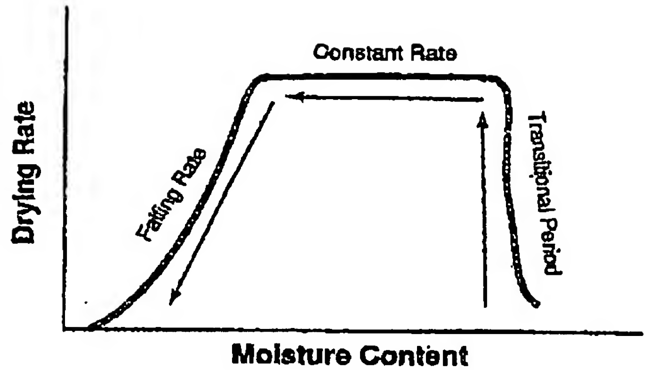
mains constant at this point, we say the web has entered a constant drying rate period. The period during which the web temperature adjusts to its equilibrium level constitutes a transition period.

Figure 7.4 shows the rate of drying to be largely independent of solvent concentration over a significant concentration range. If drying in the constant rate period is limited by external mass transport, the solvent vapor pressure must be constant throughout a drying zone in the constant rate period. At some point, the drying rate falls—either through the development of a rate-limiting internal mass transfer resistance or through a drop in the vapor pressure of the solvent over the coating. This point marks the start of the falling rate period. If the dryer is divided into zones operating under different dryer conditions, a transition period occurs at the start of each zone. Typically, these transitions last only a few seconds, although some thin-coatings may enter the falling rate period before a constant drying rate can be established.

7.3.3 Falling Rate

In one sense the falling rate period is more universal than the constant drying rate period. In the falling regime, mass transfer within the coating becomes a limiting factor, and with constant heat input, the temperature rises and the drying rate decreases. All materials exhibit falling rate behavior at some degree of dryness, but many coatings show no sign of a constant drying rate period. On the other hand, although the physics of constant rate drying are nearly universal, the mechanisms of drying in the falling rate period are more varied and more complicated. Figure 7.5 illustrates a single falling rate period as expected for internal diffusion limited drying. If the solvent is strongly complexed with the binder (or chemisorbed onto the surface of included

Figure 7.4
Typical drying curve.



solids), the rate of solvent loss may not follow this simple picture. Errede et al. (1988) indicate that in extreme cases, drying may proceed at a rate given as a sum of several exponentials, with radically different time constants, representing desorption from a number of bound states in the solid. The surface can also dry out and form a skin of the dried coating which will severely retard drying, thus producing a falling rate type drying rate curve (Figure 7.5).

7.3.4 Equilibration

Some dryers also have an additional zone after the main drying zones where the coating is treated before being wound up. Usually, this low air velocity, relatively cool zone provides residence time in which the coating can equilibrate with ambient air. Treatment may involve a process of either moisture removal or addition. For example, for water-sensitive coatings, such as gelatin, moisture is added to the film, and the film equilibrates with normal room conditions for storage because coatings can become very dry in the bulk drying zones. For processes that include a curing function, heat or some other form of energy can be introduced to provide the energy and residence time needed for the curing reaction.

These processes can also take place in the space between the end of the dryer and the winding roll. They do not require a formal drying zone. Normal ambient conditions can affect the web both in terms of equilibration and defects. If air-borne contaminants are blown onto the web, they can lead to film defects after the film is dry.

7.4 Hardware

Most web drying technology has originated and been demonstrated in the paper and printing industries before migrating to other industries based on products that use precision thin films, such as photographic film, photopolymers, or magnetic tape.

Figure 7.6 gives an overall view of the evolution of dryer process hardware. The values of the heat transfer coefficient for several dryer configurations are plotted in this figure as a func-

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